SUBTRACTIVE PRIMITIVES USED IN PATTERN MATCHING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is the first application filed for the present invention.

TECHNICAL FIELD

[0002] This invention relates to the field of machine vision and more precisely to pattern matching.

BACKGROUND OF THE INVENTION

[0003] When using present pattern matching techniques, there are situations where it is possible to incorrectly select a match for a model in a target image among a set of occurrences. Examples of such situations are illustrated below.

[0004] Figs. 3a, 1a, 1b and 1c together illustrate an example where more than one occurrence of a model is detected in a target image when using prior art techniques. Referring to Fig. 3a, the model is defined by a set of primitives 16, as in methods known in the art. For the purposes of this description, the foregoing primitives will be referred to herein as additive primitives. The dotted lines around the model primitives 16 indicate that a blank space to the left of the model primitives 16 is being sought. However, this blank space is not explicitly defined in the model.

[0005] In the target image, the likelihood of a match at a given location is measured using a similarity score, which computes the proportion of model primitives appearing at

this location. In the situation illustrated in Figs. 1a, 1b and 1c, the three located occurrences 12, 18 and 24 yield identical similarity scores of 100%.

[0006] The skilled addressee will appreciate the limitations of this prior art technique in the case where a particular occurrence of the model is sought; in the present example, an occurrence neighbored on the left by a blank space is desired and this condition is satisfied only by occurrence 12 in the illustrated target image. This is a serious drawback for many applications.

[0007] Figs. 3b, 2a, 2b and 2c together illustrate another example where more than one occurrence of a model is detected in a target image when using prior art techniques. Referring to Fig. 3b, the new model is defined as previously by a set of additive primitives 28. The dotted lines around the model primitives 28 indicate that a blank space to the right of the model primitives 28 is sought; again, this wish is not explicitly defined in the model.

[0008] In the situation illustrated in Figs. 2a, 2b and 2c, three occurrences 32, 36 and 40 of the model are located in the target image with the similarity scores shown. In Fig. 2a, a similarity score of, for example, 90% is computed since the left vertical edge of the model is missing from occurrence 32. In Figs. 2b and 2c, occurrences 36 and 40 produce identical scores of, for example, 80% since both vertical edges of the model are missing in occurrences 36 and 40.

[0009] The skilled addressee will appreciate that, if a threshold of say 70% is used for a positive match, all three occurrences 32, 36 and 40 would be considered matches for the model, while only occurrence 32 satisfies the

above-identified wish. It will be appreciated that this is a serious disadvantage.

[0010] There is therefore a need in the industry for a method that will overcome the above-identified drawbacks.

SUMMARY OF THE INVENTION

[0011] It is an object of the invention to provide a method for recognizing an object in a target image using a model defined by additive and subtractive model primitives.

[0012] According to a first aspect of the invention, there is provided a method for recognizing an object in a target image using a model defined by model primitives comprising an additive primitive and a subtractive primitive. The method comprises deriving a target primitive for the object. The method also comprises determining associations between the target primitive and the model primitives. Finally, the method comprises computing a similarity score for the target primitive with respect to the model primitives, by increasing the similarity score for each one of the associations between the target primitive and the additive primitive, and by decreasing the similarity score for each association between the target primitive and the subtractive primitive.

[0013] According to another aspect of the invention, there is provided a computer-readable storage medium on which are stored instructions to be executed by a processing unit to carry out the foregoing method of object recognition.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Further features and advantages of the present invention will become apparent from the following detailed

description, taken in combination with the appended drawings, in which:

[0015] Figs. 1a, 1b and 1c are schematics showing an example where more than one occurrence of a model is detected in a target image when using prior art techniques;

[0016] Figs. 2a, 2b and 2c are schematics showing another example where more than one occurrence of a model is detected in a target image when using prior art techniques;

[0017] Figs. 3a and 3b are schematics showing the models for the examples illustrated in Fig. 1a, 1b, and 1c and Fig. 2a, 2b, and 2c respectively.

[0018] Fig. 4 is a flowchart of a method for pattern matching in accordance with a preferred embodiment of the invention;

[0019] Fig. 5 is a flowchart showing in more detail the detection step of Fig. 4;

[0020] Fig. 6 is a flowchart showing in more detail the similarity score computation step of Fig. 5;

[0021] Fig. 7 is a schematic showing an example of a model comprising additive primitives and subtractive primitives in accordance with an embodiment of the invention;

[0022] Figs. 8a, 8b, and 8c are schematics showing an example where the additive and subtractive primitives are used in pattern matching in accordance with an embodiment of the method of the present invention;

[0023] Fig. 9 is a schematic showing another example of a model comprising additive primitives and subtractive

primitives in accordance with an embodiment of the invention; and

[0024] Figs. 10a, 10b, and 10c are schematics showing another example where the additive and subtractive primitives are used in pattern matching in accordance with an embodiment of the method of the present invention.

[0025] It will be noted that throughout the appended drawings, like features are identified by like reference numerals.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0026] Now referring to Fig. 4, there is shown the principal steps of the pattern recognition process in accordance with a preferred embodiment of the invention. According to step 62, a plurality of model primitives is acquired to define the model. Examples of primitives include straight line segments, curve line segments, points, and edge elements, commonly known as edgels. The plurality of model primitives comprises at least one additive primitive and at least one subtractive primitive. Examples of how the additive and subtractive primitives are used are discussed below. In an embodiment of the invention, additive and subtractive primitives are stored in memory (not shown).

[0027] In a preferred embodiment, the subtractive primitives are determined based on the expected false matches for a given application (e.g. by the user).

[0028] According to step 64, a target image is acquired by an image acquisition device (e.g. gray scale digital camera, electromagnetic or ultra-sonic imaging system, etc.).

[0029] According to step 66, an occurrence of the model is detected in the acquired target image using the additive and subtractive model primitives.

[0030] Now referring to Fig. 5, there is shown in more detail how the detection step 66 is performed. According to step 70, at least one target primitive is derived from the target image; the target primitives are derived according to methods known in the art. According to step 72, associations between the derived target primitive and the additive and subtractive model primitives are determined. According to step 74, a similarity score is computed using the previously determined associations.

[0031] In one embodiment of the invention, steps 70, 72 and 74 are performed according to a geometric hashing technique well known in the art. In an alternative embodiment of the invention, steps 70, 72 and 74 are performed according to a generalized Hough transform technique also well known in the art. In the geometric hashing embodiment, a hash table is used to store the model primitives. In the generalized Hough transform embodiment, an R-table is used to store the model primitives.

[0032] In yet another preferred embodiment, a position of the object in the target image is provided. In this embodiment, the additive model primitive and the subtractive model primitive comprise additive model edge elements and subtractive model edge elements respectively; also, the target primitive comprises target edge elements. In this embodiment, the association step 72 includes satisfying a neighboring condition between the target edge elements and either of the additive or subtractive model edge elements.

[0033] It will be appreciated that, in an embodiment of the invention, associations between target primitives and additive primitives contribute to increase the similarity score, while associations between target primitives and subtractive primitives contribute to decrease the similarity score.

[0034] Now referring to Fig. 6, there is shown in more detail how the similarity score computation step 74 is performed.

[0035] According to step 76, an initialization of the similarity score is performed. According to step 78, one of the previously determined associations is selected. According to step 80, a check is performed to determine whether or not the selected association is an association of a target primitive with an additive primitive. If so, the similarity score is increased (step 82). If not, the similarity score is decreased (step 84).

[0036] In a preferred embodiment of the invention the similarity score is computed as follows:

[0037] $$Similarity\_score = \frac{\sum E_{PositiveAssociated} - \sum E_{NegativeAssociated}}{N_{PositiveAssociated}},$$ where

$E_{PositiveAssociated}$ is an association with an additive primitive, $E_{NegativeAssociated}$ is an association with a subtractive primitive, and $N_{PositiveAssociated}$ is the total number of associations with additive primitives.

[0038] Also, it will be appreciated that weights may be assigned to the model primitives (additive or subtractive) when computing the similarity score. As skilled addressees

will understand, the addition of weights to model primitives affects (positively or negatively) the similarity score by putting emphasis on more important features of a model.

[0039] Someone skilled in the art will appreciate that the similarity score may be computed according to various other formulas.

[0040] According to step 86, a check is performed to determine if all associations have been considered in the calculation of the score. If there is an association left, the process returns to step 78 and selects an association that has not yet been considered. If there are no associations left, the computed similarity score is provided (step 88) and the process ends.

[0041] Fig. 7 and 8 together illustrate an example of pattern matching in accordance with an embodiment of the invention.

[0042] Fig 7 illustrates the model to be found in the target image; the model comprises additive primitives 92 and subtractive primitives 90. The dotted lines 93 are defined in order to easily reference the location of an occurrence of the model in the target image.

[0043] Fig. 8a, 8b, and 8c show three occurrences of the model in a target image (at locations 94, 98, and 104) and their associated similarity scores.

[0044] Referring to Fig. 8a, at location 94, all of the additive model primitives 92 are associated with target primitives 96; these associations contribute positively to the similarity score. No associations are made with the

subtractive model primitives 90. The resulting similarity score is 100%.

[0045] Referring to Fig. 8b, at location 98, the target primitives 102 are associated with the additive model primitives 92; these associations contribute positively to the similarity score. However, the target primitives 100 are associated with the subtractive model primitives 90; these associations contribute negatively to the score. In the illustrated situation, if the additive and subtractive model primitives have equal weights, the resulting score is 0%.

[0046] Referring to Fig. 8c, at location 104, the situation is analogous to the situation at location 98, and therefore the similarity score is 0%.

[0047] The skilled addressee will therefore appreciate that it is now possible to advantageously discriminate between objects in a target image that have the same additive primitives. The skilled addressee will also appreciate that the sought object in a target image could be incomplete to a certain degree (e.g. due to occlusion, degradation, etc.), and the method of the present invention would still find the correct match.

[0048] Figs. 9 and 10 together illustrate another example of pattern matching in accordance with an embodiment of the invention.

[0049] Fig. 9 illustrates the new model to be found in the target image; the model comprises additive primitives 110 and subtractive primitives 112.

[0050] Figs. 10a, 10b, and 10c show three occurrences of the model in a target image (at locations 114, 118, and 124) and their associated similarity scores.

[0051] Referring to Fig. 10a, at location 114, all the additive model primitives 110 except for those belonging to the left vertical edge are associated with target primitives 116. The corresponding similarity score is 90%, for example.

[0052] Referring to Fig 10b, at location 118, all the additive model primitives 110 except for those belonging to the vertical edges are associated with target primitives 120. However, the subtractive model primitives 112 are also associated to target primitives 122. The corresponding similarity score is 45%, for example.

[0053] Referring to Fig. 10c, at location 124, the situation is analogous to the situation at location 118, and therefore the similarity score is 45%.

[0054] The skilled addressee will therefore appreciate that it is possible to advantageously discriminate between the occurrences of an object in a target image as shown in Figs. 10a, 10b and 10c. In this example, if the threshold for a positive match were selected at 70%, the method of the present invention would select only occurrence 116 as a match.

[0055] Although the main object of the invention is to determine the similarity score, it will be appreciated that this score may be compared to a threshold criteria; the result of the comparison indicates whether the pattern matching is conclusive. More precisely, if the similarity score is higher or equal to the threshold criteria, the

pattern matching is conclusive; if the similarity score is below the threshold criteria, the pattern matching is not conclusive. The skilled addressee will appreciate that the threshold criteria depends on each specific application. The threshold criteria may be selected from a group comprising of a user given criteria, a computer generated criteria, a range of values, another similarity score, etc.

[0056] In a preferred embodiment, the method described above is stored on any state-of-the-art computer-readable storage medium (not shown) and executed by a processor. The foregoing storage medium and processor are meant to include, but are not limited to, a combination of a CPU with a memory device (external or internal, ROM, RAM, floppy disk, memory stick, hard drive, etc.), an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA), a circuit board, etc.

[0057] The embodiments of the invention described above are intended to be exemplary only. The scope of the invention is therefore intended to be limited solely by the scope of the appended claims.